Engineering Note
for
E906 Detector Assembly

PROJECT: E906

TITLE: Station 3 Minus Drift Chamber Support

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ABSTRACT: This document describes the fixture used to support the Station 3 Minus (lower) drift chamber in E906.

OVERVIEW:
The station 3 Minus detector recycles drift chambers previously used on E866. The detector consists of three separate aluminum chamber frames mounted in a steel support. The chamber support sits on the SeaQuest Hall floor (See Figure 1)

This note addresses the installation of the chamber and the stand built for E906. The construction of the E866 chambers should be covered in a previous engineering note.

Each of the three chambers weighs approximately 600lbs.
Each chamber is constructed on an aluminum 6061-T6 2"x 4" C channel welded frame.
The open side of the C channel faces outward.
Figure dimensions are in inches.

DESIGN:
The support stand is constructed of ASTM A-500 2x2, 3x3 and 2x4 steel box tubing (1/4" wall thickness). The tubing is welded together to form two stand halves (see Figure 2). Each half has two beams that provide a base and a vertical section on one side. The two halves are joined with bolts where the base beams meet along the hall floor. The connected stand rests on the hall floor.

An aluminum pad is placed into the aluminum C channel chamber frame at each bottom corner. The pad is connected to the chamber using a ¼-20 SHCS (McMaster Carr Part 91251A551) into an existing ¼" hole on the chamber (see figure 3 and 6).

An equipment leveling foot (McMaster Carr part 62805k41) rated for 500lbs is threaded into the pad at each bottom corner. The foot allows up to 2" height adjustment

The leveling foot rests on a ¼" steel plate that is welded to the box beam support knee. The weight of the chamber is on this steel plate.

The vertical section is a tall post of 3x3 box tubing with a comb shaped weldment at the top. The machined slots making the comb are to resist movement forward/aft movement of the detector. The comb slots are located above the chamber center of gravity.

An aluminum pad is positioned on each side of the chamber. The aluminum pad is secured with a ¼-20 SHCS (McMaster Carr part 91251A551) into an existing hole on each side of the chamber. The pad center has a tapped hole for a ½-13 grade 5 bolt (McMaster Carr part 92865A738). The 1/2" bolt is positioned in the comb slot. Nuts are used on each side of the comb to mark the position. The chamber position when aligned to the beam height places the bolt above the low point of the comb slot. These side pads are not intended to support chamber weight.

The E906 installation requires a 90 degree rotation of the 3 E866 chambers. The E866 lifting points were removed. New steel lifting pads are affixed. The two steel lifting pads

are attached to the chamber using 3/8” bolts thru both flanges of the C channel. (see Figure 5 & 7) The lifting pads are tapped to accept a ½” hoist ring.

Installation:

The chambers are lifted vertical using the hoist rings. The leveling feet are attached. The chamber is lowered into the support so the pad rests on the flat plate and the ½” bolts are located in the comb slots. Removal for service is in the reverse order.

ANALYSIS:

The center of mass for a support half is located above the knee plate (See Figures 8 & 9). The chambers are approximately symmetric with a center of mass at their centers. The combined center of mass for the detector assembly is 9.25” below the center of the middle chamber. These values were obtained from the assembly model in Autodesk Inventor 2010. (See figures 11 & 12)

The stand is most unstable when loaded with a single chamber in an upstream or downstream position. The force of a single chamber about the X axis direction through the center of mass of the support is:

Force about Support center of mass X direction = 300lbs x sin (12.1)
= 63lbs. (see Figure 9)

This force is about 20% the weight of the stand half alone. For the detector to topple there would need to be a moment about the support base end opposite to that of the support. The combined forces are in a downward direction at about 13 degrees from vertical. This line of force is within the base of the support. The force of a chambers center of mass along the Z direction adds to the stability of the assembly. The force about the Y direction is negligible. The detector is stable from tipping due to the chambers.

Knee:

The adjustable leveling feet of the 3 minus chambers rest on a ¼” steel plate. The steel plate is welded to a steel knee constructed of 2x4” and 2x2” steel box beam. Three chambers with a weight per side of 300lbs yield a 900lb load on each knee. The box tubing is ASTM A500 steel with a minimum tensile stress of at least 45ksi. The weld filler material used was 60XX series with allowable shear strength of 18ksi.The knee weldment is constructed using 3/16” fillet weld.

The analysis of the weld between the horizontal beam in the knee weldment and the 3x3 vertical post (see Figure 10) uses Table XXI page 4-77 of the Steel Construction Manual 9^{th} ed

The allowable load $P = CC_1Dl$

$l = 4$

$kl = 2$

$al = 10$

$a = 2.5$

C_1 = weld filler material 60XX = 0.857

$D = 3$ for 3/16 weld size

K = .5
C = 0.177 for a = 2.4 using k = 0 for an out of plane load
P = (0.177)(0.857)(3)(4) = 1.82ksi

The area of the weld for this joint is = (3/16")(0.707)(12in weld) = 1.6in^2
The stress on the weld for this joint is = 900lbs/1.6in^2 = 563psi

The analysis of the weld between the two horizontal 2x4 box beams is similar. The load on this weld is approximately in the plane of the weld.
The allowable load P = CC_1Dl
l = 4
kl = 2
al = 0
a = 0
C1 = 0.857
D = 3
k = 0.5
C = 1.67 for an a of 0.06 the lowest value in the table
P = ((1.67)(0.857)(3)(4) = 17ksi

The stress on the welds is well below the allowable stresses. These two welded box beam sections are strong enough to hold the chambers without additional structure. The ¼" plate welded to the top and the two 2x2" legs on the tee fore and aft ends add additional strength.

Comb:
The comb is a ½" steel plate weldment with slots machined in the vertical plate to accept the chamber side locating bolts. (See figure 2) The slotted plate is welded perpendicular to a base plate. The two are braced using a 4 x 6" plate on each end. The welds are 3/16" filets.

The comb is welded to the top of the 3x3 vertical post. The weakest point on this weldment is the connection of the comb box to this post. The analysis of this weld uses Table XXI page 4-77 of the Steel Construction Manual 9th ed
The allowable load P = CC_1Dl (see Figures 1 & 2 for dimensions)

l = 3
kl = 3
al = 7.3
a =2.4
C_1 = weld filler material 60XX = 0.857
D = 3 for 3/16 weld size
K = 1
C = 0.177 for a = 2.4 using column 0 for an out of plane load
P = (0.177)(0.857)(3)(2) = 1.365ksi

The slots in the comb are 0.0531" in width and approximately 57" from the knee plate. A ½" locating bolt will allow a vertical chamber to tilt Tan^{-1}(.0.031/57) = 0.031 degrees in the slot.

Half the chamber weight of 300lb will place a side load on one bolt of

Force on bolt = 300lbs Sin (0.031) = 0.16lbs.

This force on the 5" bolt places a stress on the aluminum pad and chamber C channel.

Stress at pad = Moment / Section modulus (using circular cross section modulus)
= (0.016lbs) (5in) / [(0.098175)(0.5in)^3] = (0.8) / (0.098175)(.125) = 65psi

The fastener hardware is grade 5 with tensile strength of 180ksi. The allowable shear strength should be 17% of tensile strength for 30ksi. The aluminum pad and chamber are 6061-T6 with allowable shear stress of 14ksi. The forces on welds and these components are small and well below the allowable shear strengths of the welds, fasteners, steel or aluminum. The side supports are strong enough for the expected loads.

Rigging pads:
A 1" thick steel lifting pad of A36 steel is affixed to the top corners of each detector. The aluminum 4x2 C channel has two holes through both 0.25"flanges.(see Figure 4 & 5) The rigging pad is attached using two 3/8-16 SHCS bolts (McMaster Carr part 91251A651) Grade 8 steel and conforms to ASTM A574. The bolts have a tensile strength of 180ksi. Using an allowable shear of 17%F_u=30.8ksi as per ASD 9th ed. table I-D.

The sheer load on each bolt
300lbs/2 = 150lbs
Tensile stress area for 3/8-16 fastener = 0.0775in^2
Shear load = 150lbs/0.0775in^2 = 1935psi

Tear out of aluminum C channel (see Figure 4)
2x4 6061-T6 aluminum C channel minimum yield strength = 35ksi
Load on a 0.397 hole = 150lbs
Effective cross sectional area
Area = (2 flanges)(0.884in)(2)(0.25 thickness) = 0.884in^2
Shear on hole = 150lbs/0.884 = 170psi

Tear out of the rigging pad (See figure 7)
Steel rigging pad A36 steel with minimum yield strength of 36ksi
Load on a 0.397 hole = 150lbs
Effective cross sectional area (0.53)(2)(3.5) = 3.71in^2
Shear on hole = 150/3.71 = 40.4 psi.

The load on the bolts is within acceptable limits, the pad and the aluminum C channel are adequate to secure the lifting pads.

Hoist rings:

The ½-13 hoist rings used to lift the aluminum C channel framed chamber vertical are also used to lift the assembly and place it on the stand. Each hoist ring supports

approximately 300-lbs. The area of a ½-13 bolt, based on a minor diameter of 0.4041-in^2, is 0.128-in^2 and the resulting shear stress in each eyebolt is 300/0.128 = 2344psi. We have identified swivel eyebolts made from forged alloy steel type AISA-SAE 4140 (American Drill Bushing, part number 33515) with a minimum tensile strength of 180ksi. These bolts are certified for a work load limit of 2500-lbs with a pivot range of 180 degrees and a swivel range of 360 degrees and are suitable for this application.

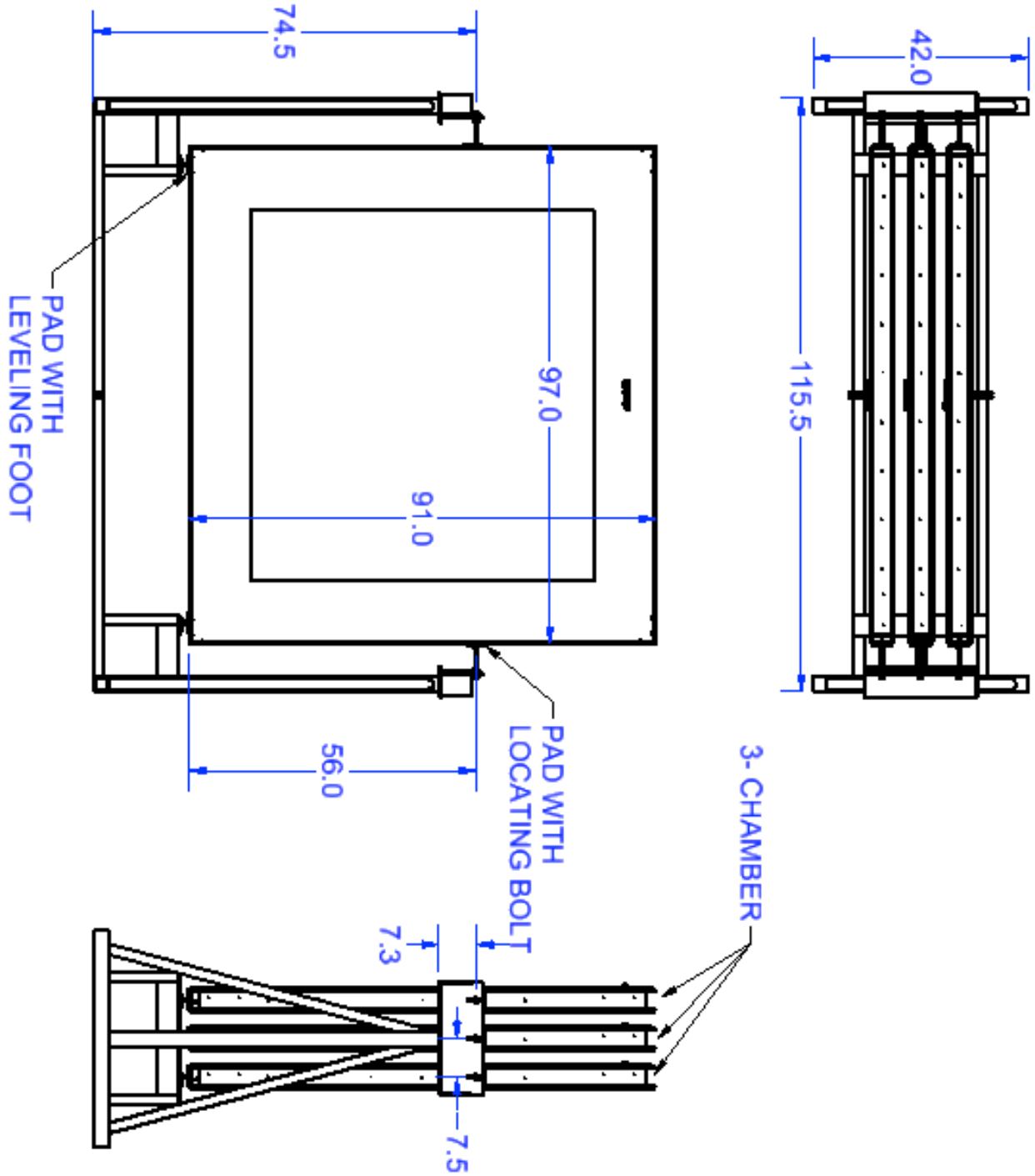
74.5
42.0
115.5
97.0
91.0
PAD WITH
LEVELING FOOT
56.0
PAD WITH
LOCATING BOLT
3- CHAMBER
7.3
7.5

Figure 1

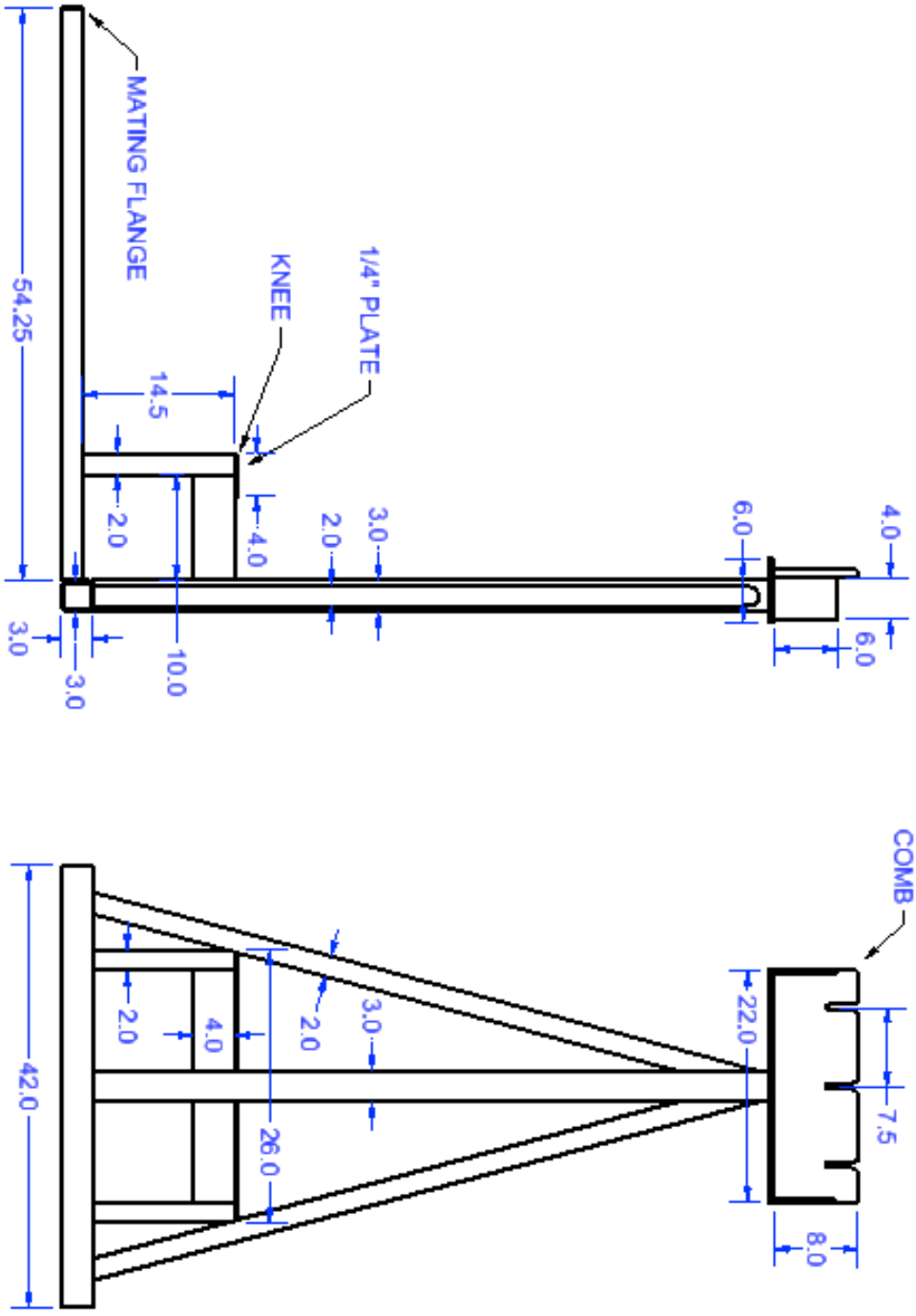
MATING FLANGE
KNEE
1/4" PLATE
54.25
14.5
2.0
4.0
2.0
3.0
6.0
4.0
3.0
3.0
10.0
6.0
COMB
42.0
2.0
4.0
2.0
3.0
22.0
7.5
26.0
8.0

Figure 2

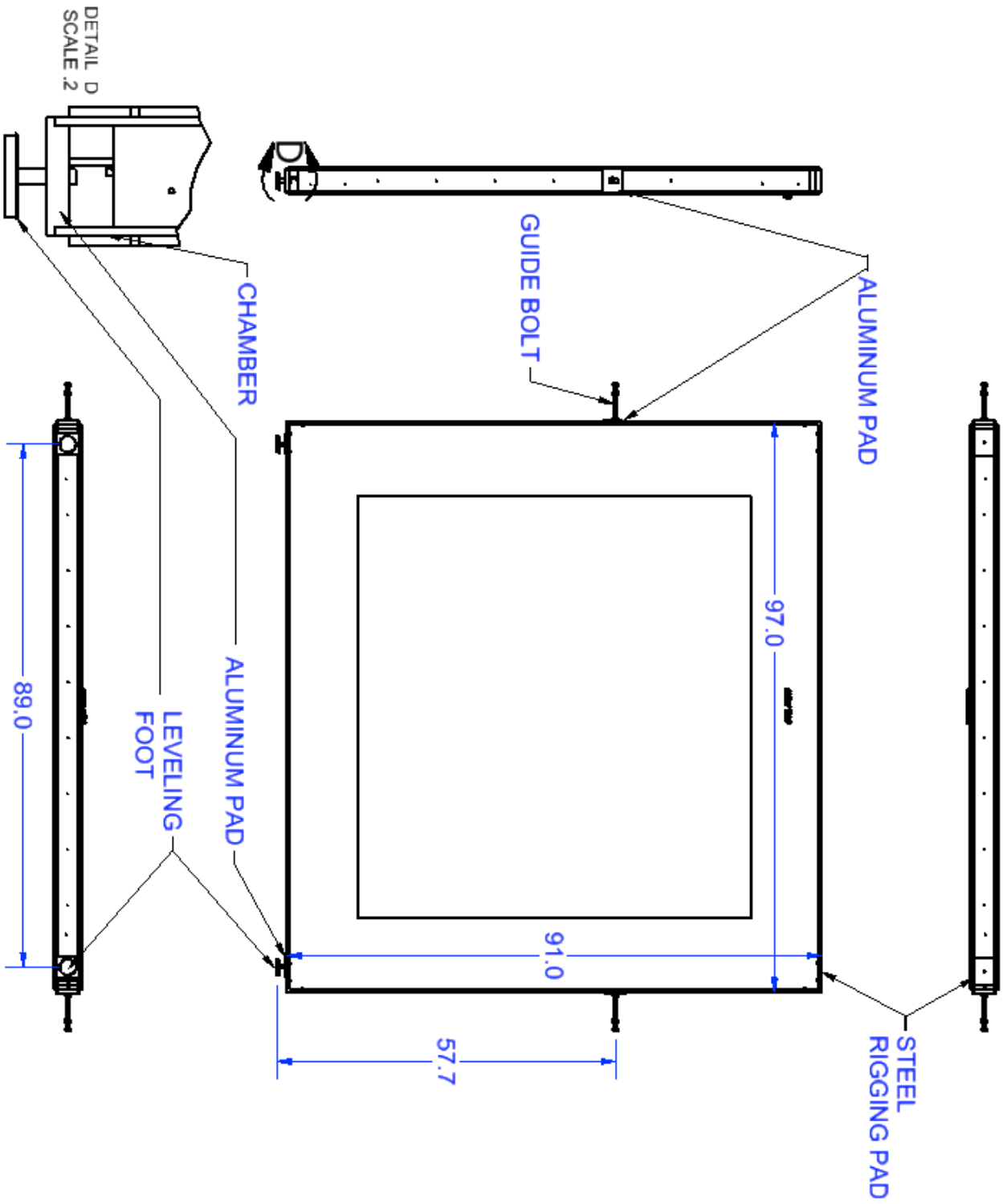
DETAIL D
SCALE .2
CHAMBER
GUIDE BOLT
ALUMINUM PAD
97.0
89.0
LEVELING FOOT
ALUMINUM PAD
91.0
57.7
STEEL RIGGING PAD

Figure 3

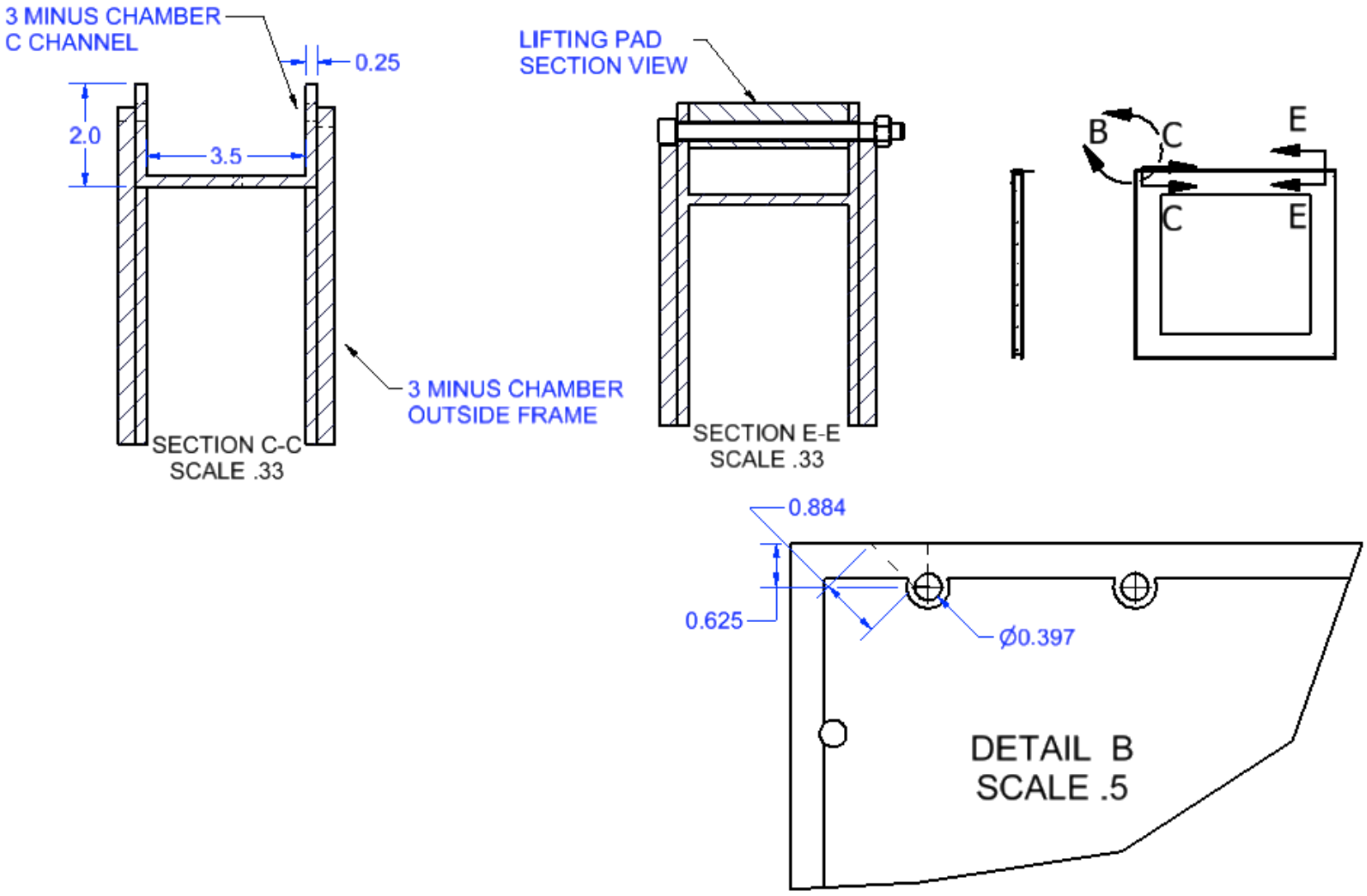
3 MINUS CHAMBER
C CHANNEL
0.25
2.0
3.5
3 MINUS CHAMBER
OUTSIDE FRAME
SECTION C-C
SCALE .33
LIFTING PAD
SECTION VIEW
SECTION E-E
SCALE .33
B
C
E
C
E
0.884
0.625
Ø0.397
DETAIL B
SCALE .5

Figure 4

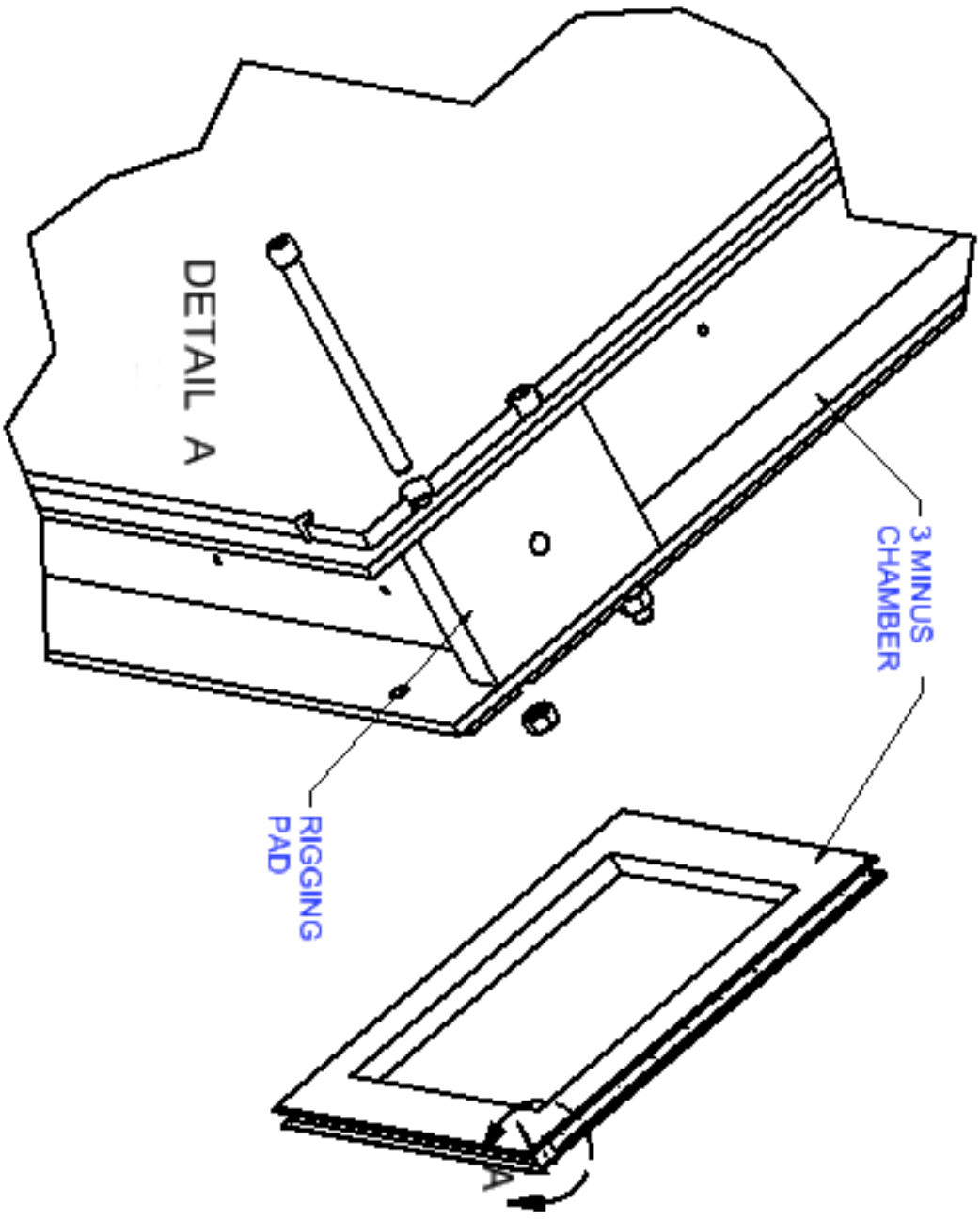

Figure 5

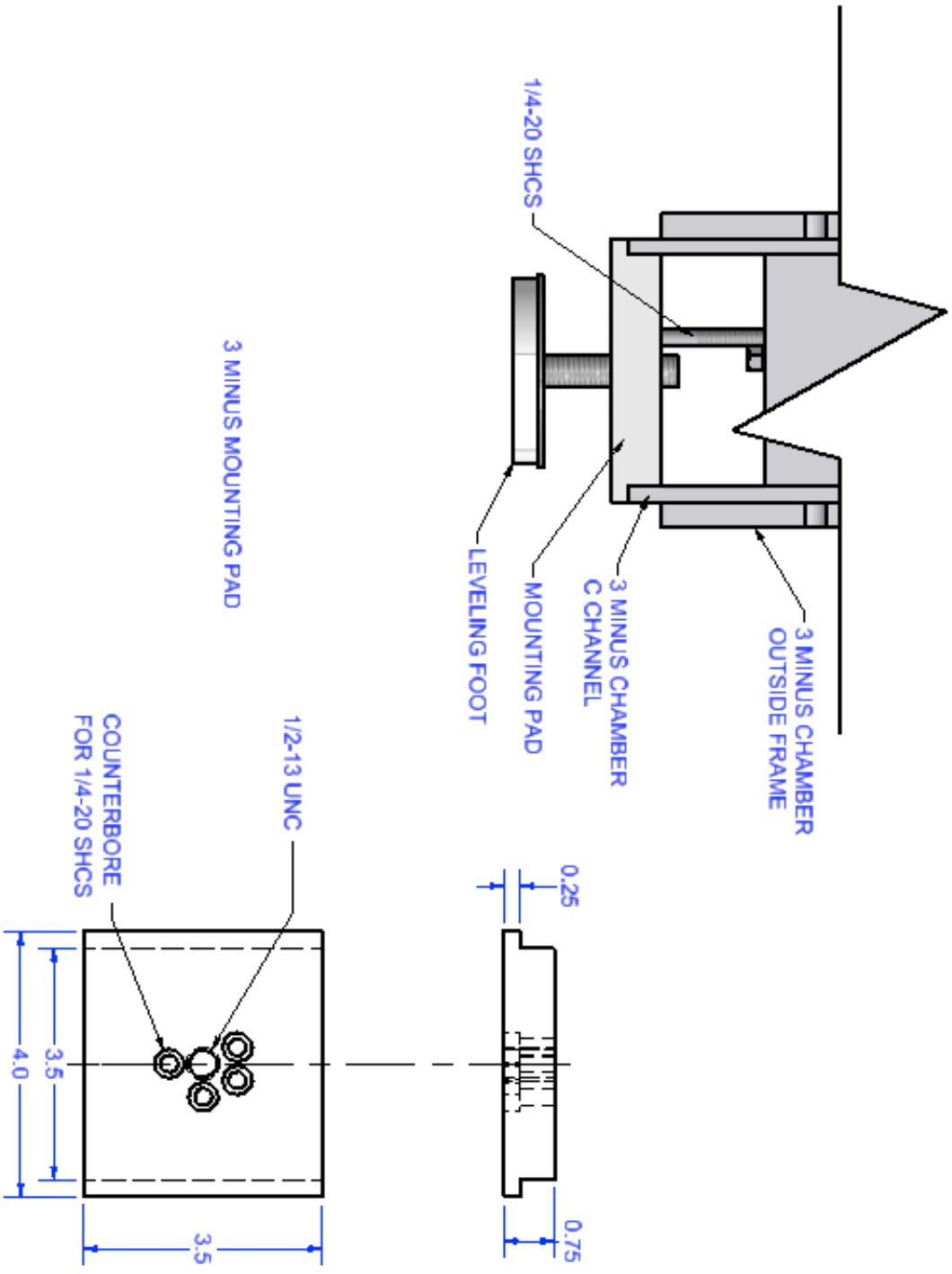
1/4-20 SHCS
3 MINUS CHAMBER
OUTSIDE FRAME
3 MINUS CHAMBER
C CHANNEL
MOUNTING PAD
LEVELING FOOT
3 MINUS MOUNTING PAD
COUNTERBORE
FOR 1/4-20 SHCS
1/2-13 UNC
0.25
0.75
4.0
3.5
3.5

Figure 6

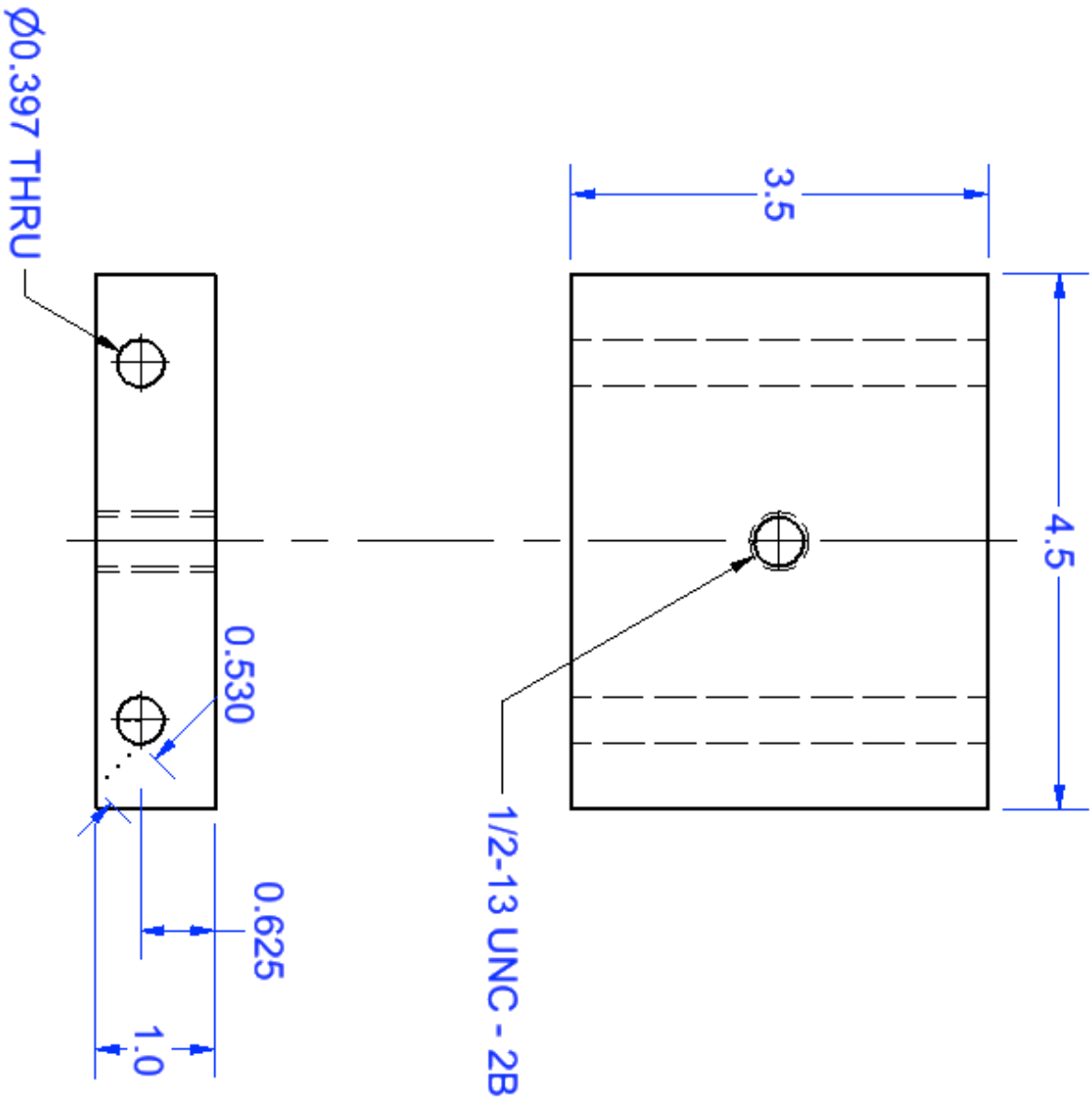

Figure 7

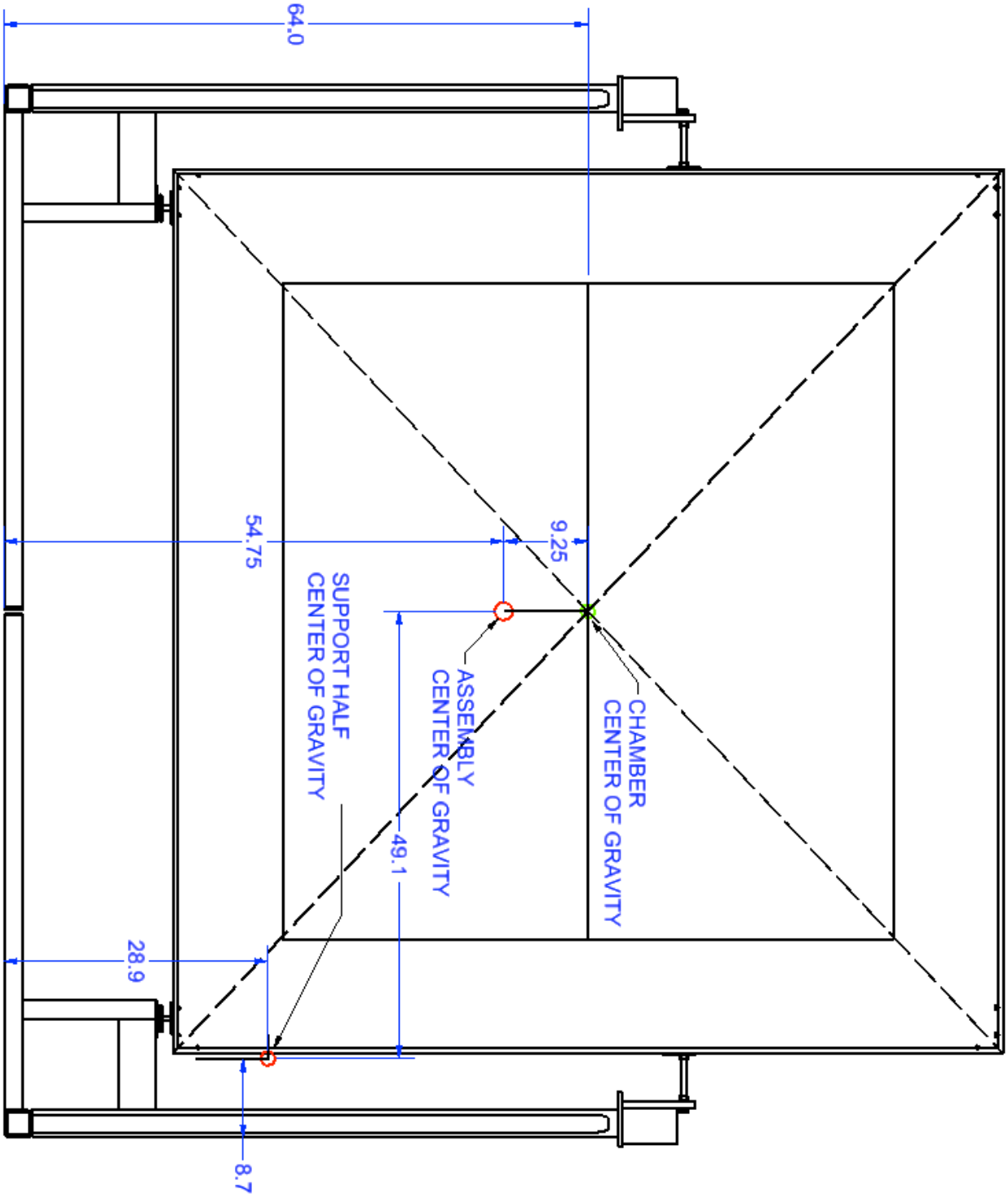
64.0
54.75
9.25
SUPPORT HALF
CENTER OF GRAVITY
ASSEMBLY
CENTER OF GRAVITY
CHAMBER
CENTER OF GRAVITY
49.1
28.9
8.7

Figure 8

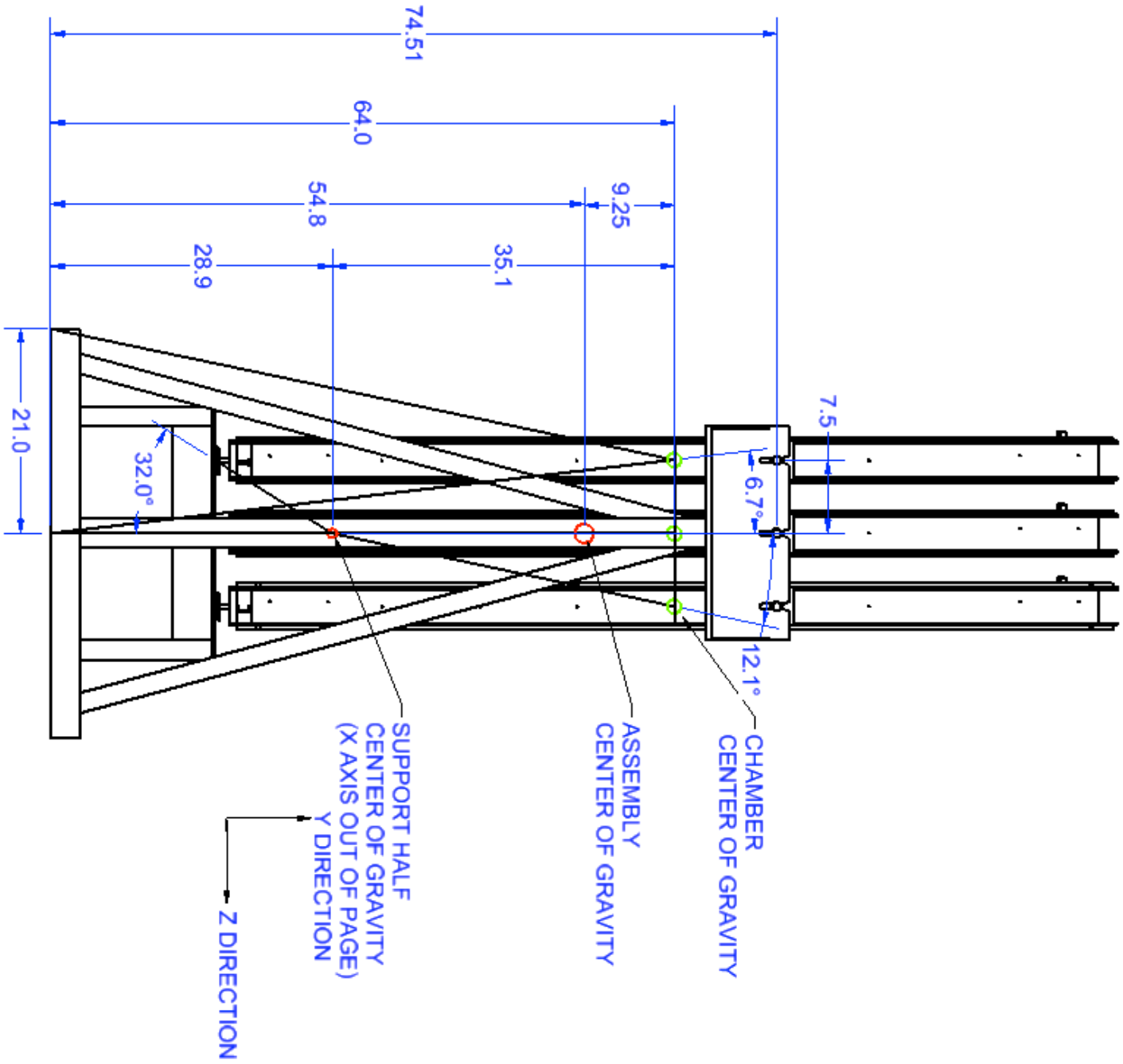
74.51
64.0
54.8
9.25
28.9
35.1
21.0
32.0°
7.5
6.7°
12.1°
SUPPORT HALF
CENTER OF GRAVITY
(X AXIS OUT OF PAGE)
Y DIRECTION
Z DIRECTION
ASSEMBLY
CENTER OF GRAVITY
CHAMBER
CENTER OF GRAVITY

Figure 9

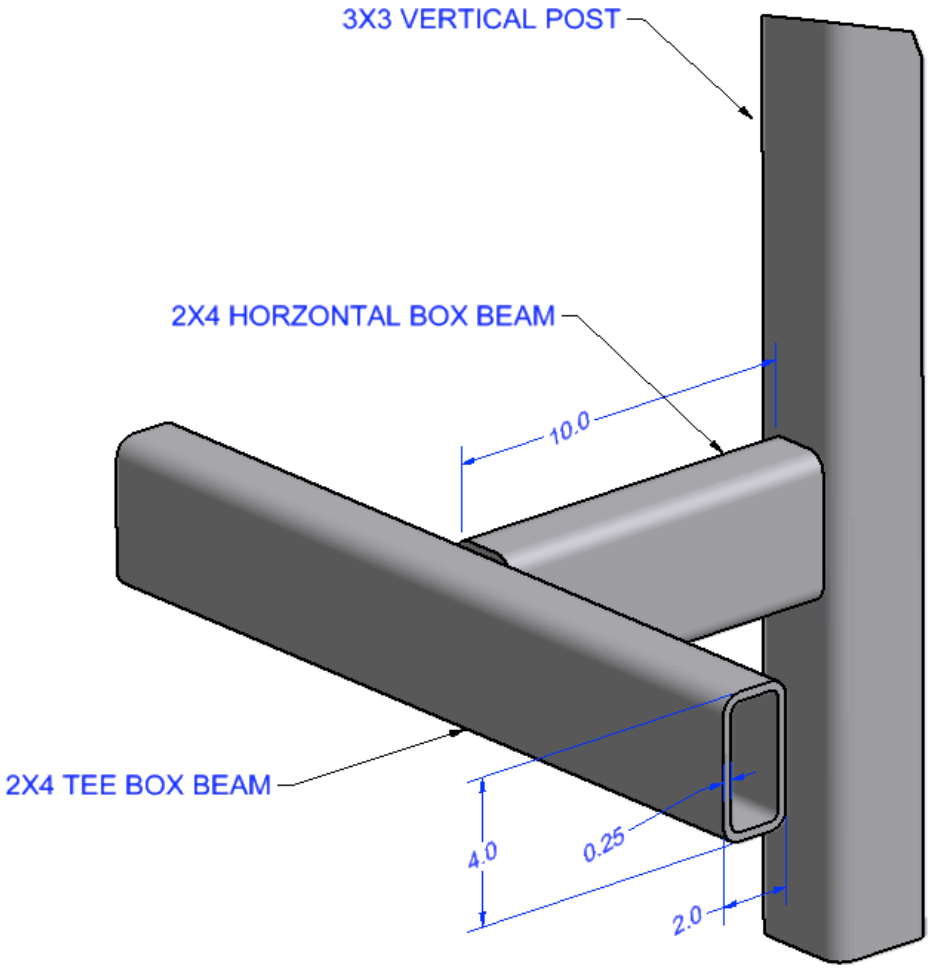
3X3 VERTICAL POST
2X4 HORZONTAL BOX BEAM
10.0
2X4 TEE BOX BEAM
4.0
0.25
2.0

Figure 10

Physical Properties for 3minus_box_stand
From Autodesk Inventor 2010
General Properties:
Material: {Steel}
Density: 7.860 g/cm^3
Mass: 286.241 lbmass (Relative Error = 0.000047%)
Area: 7282.992 in^2 (Relative Error = 0.000011%)
Volume: 1008.029 in^3 (Relative Error = 0.000047%)
Center of Gravity:
X: 0.000 in (Relative Error = 0.000047%)
Y: 28.915 in (Relative Error = 0.000047%)
Z: -8.648 in (Relative Error = 0.000047%)

Figure 11

Whole Assembly

Physical Properties for 3minus_chamber_support
From Autodesk Inventor 2010

General Properties:
Material: {}
Density: 3.265 g/cm^3
Mass: 2172.745 lbmass (Relative Error = 0.000096%)
Area: 78310.890 in^2 (Relative Error = 0.000035%)
Volume: 18420.486 in^3 (Relative Error = 0.000096%)
Center of Gravity:
X: -0.009 in (Relative Error = 0.000096%)
Y: -9.272 in (Relative Error = 0.000096%)
Z: -0.00 in (Relative Error = 0.000096%)

Figure 12